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ORIGINAL RESEARCH

Development of IoT based smart monitor and control system using MQTT protocol and Node-RED for parabolic greenhouse solar drying

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Abstract The drying process is a method to preserve and improve the taste, flavor, and texture of ripe bananas. During natural sun drying, dust, rain, insects, pests, and microorganisms may contaminate bananas. As a result, the Parabolic Greenhouse Solar Dryer (PGSD) was created to protect bananas from the contaminations. However, a human inspection of the conditions in PGSD is required to ensure the product's quality. Using modern technology to monitor and control the conditions in PGSD rather than humans is then essential. Due to the advantage of Internet of Things (IoT) technology and wireless sensor networks, this works aims to developed smart monitor and control system using IoT, MQTT and Node-RED for PGSD. The developed system can monitor temperature and humidity inside PGSD using low cost IoT. The acquisition data will transmit data through MQTT protocol and then, real-time data visualization dashboard was engendered by Node-RED. LINE notify is easy to use to notify farmers in case of deviant situation happen inside PGSD. The system can be assisted farmers by getting live data from PGSD to take a necessary step to enable them to do smart solar dryer by also increasing the values of drying bananas and saving resources.

Keywords Internet of Things (IoT) · MQTT · Node-RED · Solar dryer

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1 Introduction

Bananas (*Musa* spp.) are one of the important tropical fruits in several countries, especially in Thailand [1]. Many varieties of bananas, namely Kluai Namwa, Kluai Hom, Kluai Kai, are grown in Thailand. Among these, Kluai Namwa (ABB genome type) is the most common banana variety that yielded around 660 metric tons in 2019 or accounting for 70% of total banana yield in 2018–2019 [2]. Banana is commonly consumed as fresh fruit. The fresh banana contains natural sugars, protein, fat, potassium and vitamin A, B complex and C [3]. However, ripe banana has a soft peel and is vulnerable to being damaged during transportation, hence the need for appropriate methods to prolong shelf life. The drying process is one of the appropriate methods to minimize the loss of ripe bananas [4]. Moreover, the purpose of banana drying is not only for preservation, but also for improvement of taste, flavor, and texture of banana as well as to increase market value of the product [5]. Dried banana is a popular snack food in many countries, including Thailand. In 2021, export value of dried banana from Thailand was more than 146 million THB [6].

Natural sun drying is a traditional method to preserve ripe banana by reducing its moisture content. In nations that are tropical or subtropical, this strategy is still widely used. However, the product losses can occur during the natural sun drying due to contamination of dust, rains, insects, pests, and microorganisms [7]. Solar greenhouse dryer is, therefore, developed to overcome these issues. Over the past 50 years, researchers in different countries have developed a variety of solar dryers [8–20]. However, one of the most popular commercial solar dryers is the parabolic greenhouse solar dryer, which has been deployed in Thailand and other countries [21–24]. Because the dryer has a simple and uncomplicated operation, it can prevent damage from animals and from weather changes such as rain. In addition, parabolic greenhouse solar dryers are available in suitable sizes, which can satisfy the needs of users and have an acceptable cost. However, the operator must periodically inspect the solar dryer to check the greenhouse condition and the condition of the dried banana products to ensure product quality [25].

Optimal control of the conditions inside the Parabolic Greenhouse Solar Dryer (PGSD) will ensure quality-dried bananas [25]. Therefore, important parameters such as temperature, relative humidity, and airflow rate should be monitored and investigated during the drying process.

2 Proposed system and implementation

The proposed objective of this works is to monitor and control temperature and humidity of indoor agriculture using low cost IoT. Both Free and Open Source Software (FOSS) and Open Source Hardware (OSH) such as Visual Studio Code, Arduino IDE, WeMos D1 board controller, NodeMCU ESP32 are selected to use for this work. IoT sensors are used to collect the air temperature and humidity data inside the PGSD. We have installed it by placing it in 3 positions which are front, middle, and rear of the PGSD to measure temperature and humidity in each zone. We also fixed temperature and humidity sensors outside to invention the affiliation between the environment inside and outside the PGSD. The sensor data is transmitted from ESP8266 using WeMos D1 board controller to the Node-RED platform via MQTT protocol. In this work, we divided the function of the sensor into 2 systems: first, the monitoring system, the temperature and humidity monitoring system. This system will collect and transmits the sensor's data to the Node-RED through MQTT, and then Node-RED will record into the database using HTTP client, at the same time it will shows the real-time dashboard for displaying this measured data. The second part is the controlling system, to send the notification to staff from Node-RED to alert via LINE Notify. Then, the staff/farmer can control the fan system from mobile devices through Node-RED and MQTT published message (Fig. 1).

(1) The temperature and humidity monitoring system.

In this system, we developed a sensor to measure temperature and air humidity data at three nodes inside the plant and one node outside. WeMos D1 and DHT22 were used. The WeMos D1 is a ESP8266 Wi-Fi based board that uses the Arduino UNO layout with operating voltage of 3.3 V. However, this is not an Arduino board, it only uses the Arduino Uno layout for the board design. The board is controlled by the ESP8266 chip (a 32-Bit processor) and has a larger flash memory compared to an Arduino Uno. It consists of 11 digital I/O pins and 1 analog input pin. The board can be connected using a Micro-B type USB cable. Due to WeMos D1is a ESP8266 WI-FI based board, thus, it is a great platform for any smart home, smart device system that can create an MQTT communication, control outputs, read inputs and interrupts [26–28]. The DHT22, also known as the digital-output relative humidity and temperature sensor, is a temperature and humidity sensor

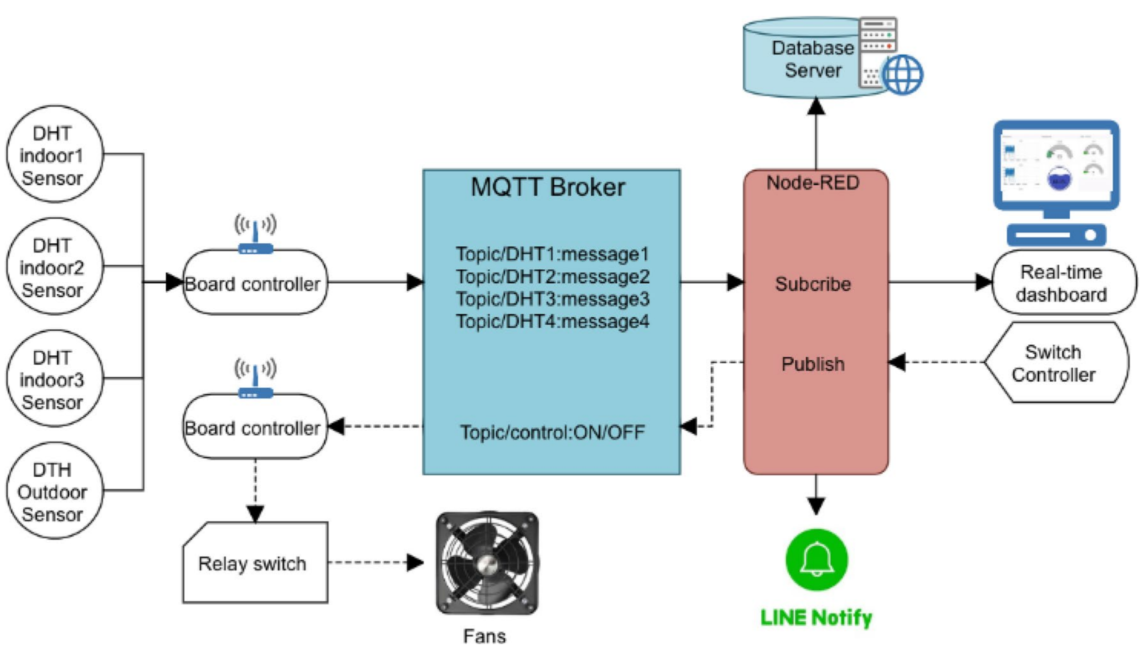

Fig. 1 The proposed of the smart PGSD system

interface used to sense air humidity and temperature. Digital signals calibrated by DHT22 are output. It makes use of proprietary digital signal collection and humidity sensor technologies, guaranteeing its dependability and stability. Every sensor in this model is temperature corrected, calibrated, and stored in a type of programmed memory called OTP. When the sensor is detected, it will get the calibration coefficient from memory. The DHT22 type runs on a 3.3–6 V DC power supply with an operating range of − 40 to 80 °C and a range of 0–100% relative humidity (RH). Temperature +/− 0.5 °C, humidity +/− 2%RH (max +/− 5%RH). Small size and long consumption and long transmission distance or around 20 m enable DHT2 to be suited in this work. Figure 2 shows the internal structure of the node that used for monitoring temperature and humidity data.

(B) The controlling system.

The controlling system plays a key role in designed system to control temperature and humidity values inside the PGSD. In this system has been using a development board that can support both raspberry zero and NodeMCU esp32 and moreover, this board comes with a 7-channel relay as shown in Fig. 3. The development board support to use main power 9–30 V DC and power for opto-isolator 5 V DC with 3 digital input/output a 1 universal push button switch. The main reason for choosing this kit is because that it provides a stable installation relay 7 channel rather than a separate system connection. NodeMCU esp32 can connected to Wi-Fi and communicate with MQTT protocol. The scalable and adaptive ESP32 chip serves as the module's central processing unit. Wi-Fi and Bluetooth are integrated into the module.

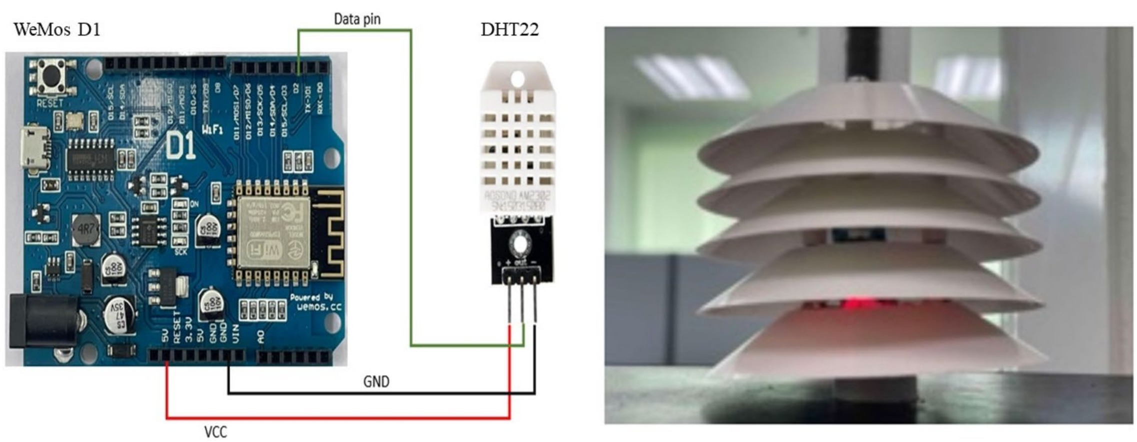

Fig. 2 The internal structure of sensor and equipment box

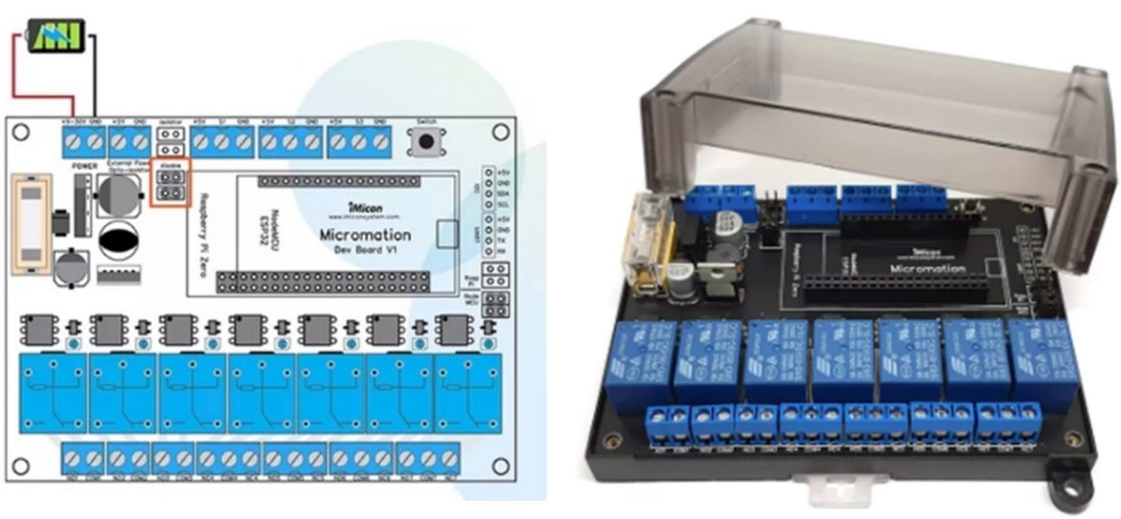

Fig. 3 The development board using NodeMCU esp32 installed 7-chanel relays

Wide range of applications: Bluetooth allows users to connect to a mobile phone or emit a BLE Beacon for signal detection; Wi-Fi supports a wide range of communication links, as well as direct Internet access via a router. For the best wireless connectivity, the module offers data rates of up to 150 Mbps and antenna output power of 20 dBm. As a result, this module has industry-leading specifications and performs well in terms of high integration, wireless transmission distance, power consumption, and network connectivity. In this works, we use the main power from solar cell. The solar panel converts sunlight into DC electricity to charge the battery 12V45Ah. Then, DC electricity is fed to the battery via a solar regulator which ensure the battery is charged properly and not damaged. The main power from battery is passed through the timer before being supplied to the control board. We set timer to reset the board every 3 h to be sure that the Internet connection is not lost the signal. At the same time, it will be supplied to the power system through the relay and wait for the ON/OFF message form the control board via Node-RED and MQTT. The internal structure of controlling unit shown in Fig. 4.

The development of the controller can control electrical equipment up to 7 points, which can be controlled either by manual system, in front of the cabinet by switching the switch to Manual or waiting for control message from mobile phones by switch to Auto mode.

3 Result and discussion

Both systems in this work operate by connecting to an MQTT broker (Message Queuing Telemetry Transport). Using the Ubuntu operating system, Mosquito has been installed on the server. Mosquito is an open source software (OSS) used for MQTT brokers. MQTT is a publish/subscribe communication protocol that enables a network of protocol-enabled devices to send data to a broker. MQTT can be used for telemetry and sensor machine-to-machine (M2M) applications as well as mobile applications. There is a message broker involved in the public/subscribe messaging pattern. As a result, in MQTT, the MQTT broker serves as an intermediate, forwarding messages to subscribers based on the message's topic once they have been received from publishers. The flowchart for monitoring and controlling systems is depicted in Fig. 5.

The monitoring system will publish data from sensors into 6 separate topics to MQTT broker. Then Node-RED will display on real-time dashboard as number, continuous chart, or text, and send data into database server via HTTP clients. A low-code programming tool called Node-RED can be used to connect hardware components, APIs, and web services in new and interesting ways. It offers a browser-based editor that makes it simple to connect flows for receiving, sending, processing, transforming, and storing

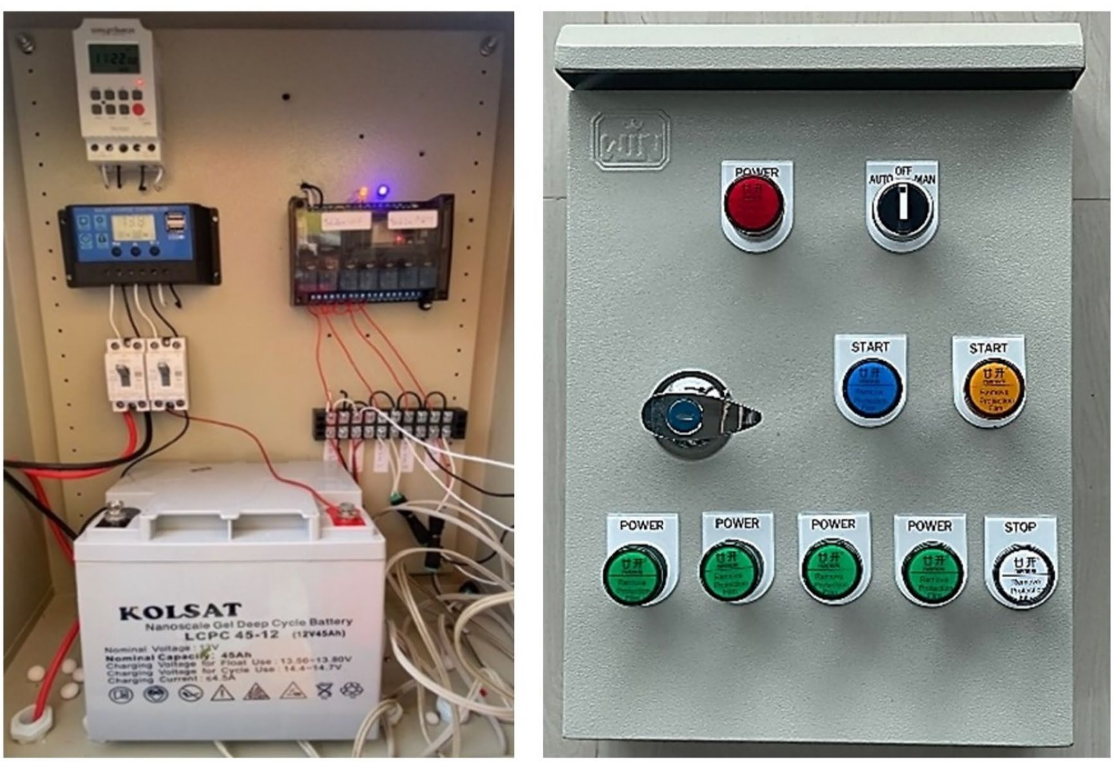

Fig. 4 The developed control cabinet

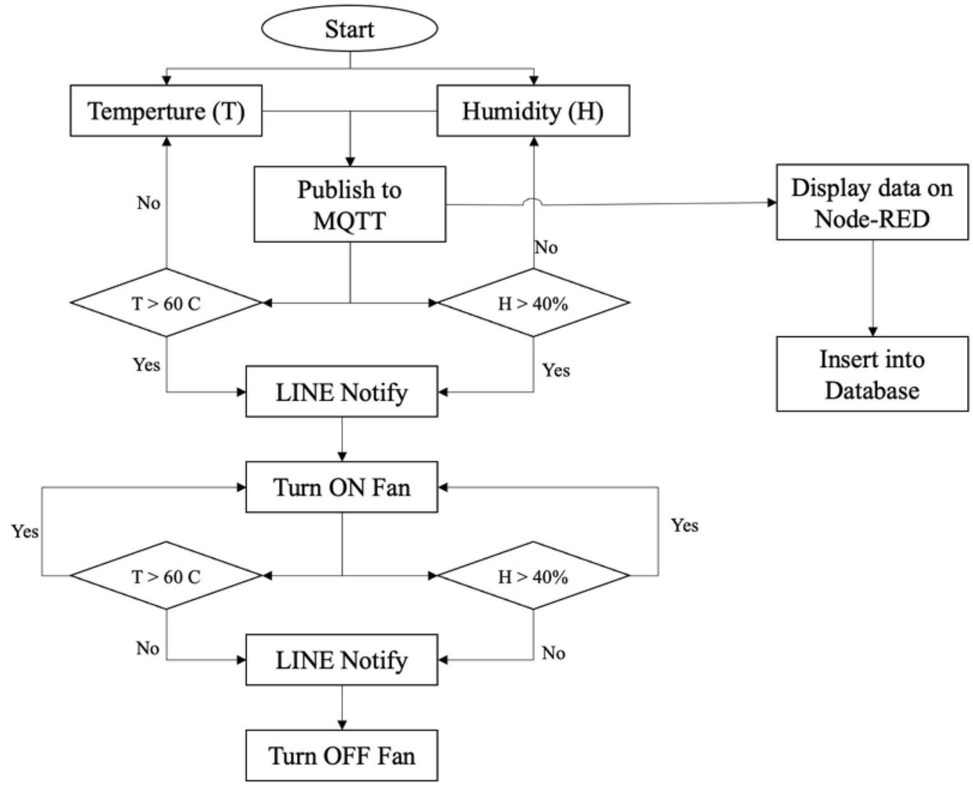

Fig. 5 The monitoring and controlling flowchart

using a variety of nodes from the palette that has more than 4000 modules, including the MQTT subscribe and publish module (Fig. 6), which can be deployed to its runtime with just a single-click. The event-driven, non-blocking approach of Node.js, on which the lightweight runtime is based, is fully utilized. Because of this, it can run both in the cloud and at the network's edge on inexpensive hardware like the Raspberry Pi. In this works, we have installed Node-RED on cloud.

This system is easy way to generate the user interface (UI) on web-application based using the node-red-dashboard module in the palette that makes developers faster to develop IoT application platform.

Figure 7 show the flow for sending the data to database server, the www-request node (HTTP request) connects to our database system API using GET method to send the data from MQTT into database server then the node-red-debug provided the HTTP response. The data from MQTT

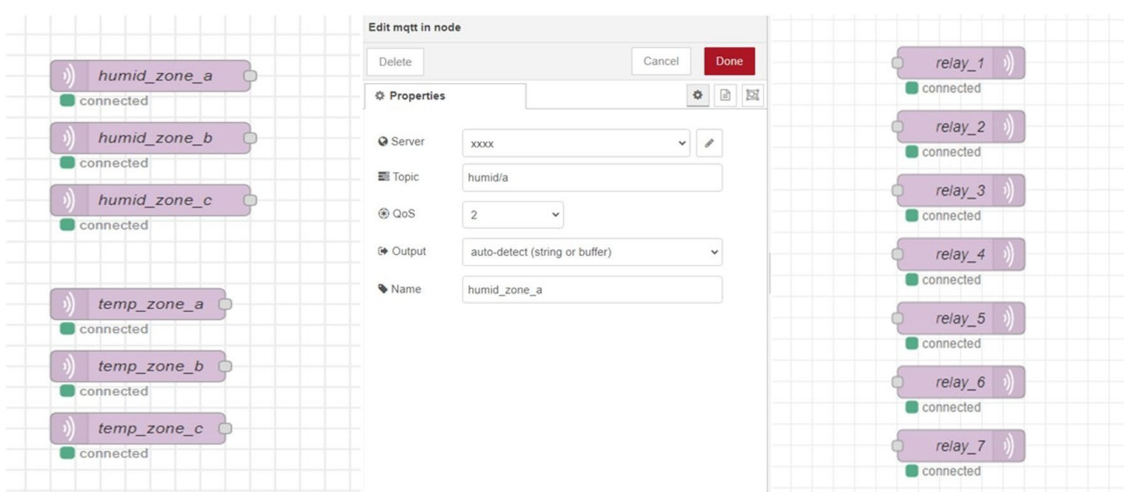

Fig. 6 MQTT subscribe and publish node

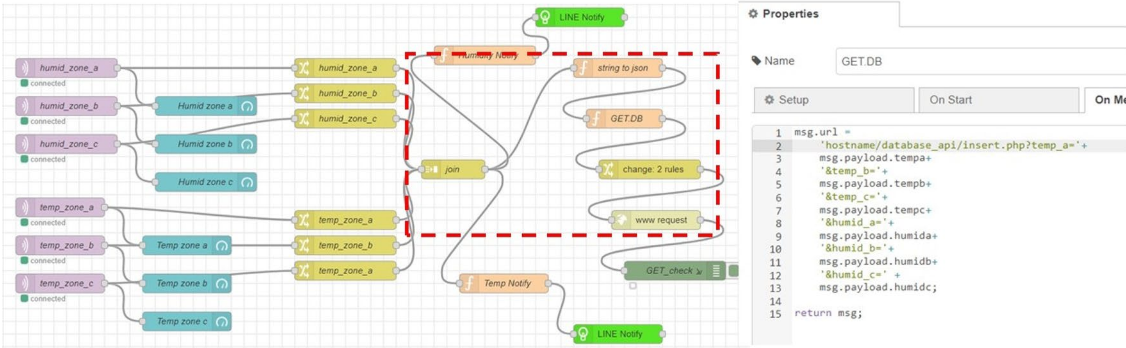

Fig. 7 HTTP request for sending the data to database server API

subscribe nodes were flowed to merge the data to JSON object including its name and data like data = {humid_a= "XX", humid_b= "YY", …}. Then, the data object was restructured to string as msg.payload.humida, msg.payload.humidb, …, and it was used in API path using msg.url in GET.DB node for sending the data. The HTTP method was set to GET as msg.method. Finally, the data, API path, and HTTP method were flowed to www-request node (Client) and published to database server. The response from database server was send back to to www-request node and showed the response using debug node (GET_check). From the reading recorded into database shown in Fig. 8. The recording is perfectly captured at their specific column without injection on bad data from sensor. The result of database automatically insert into database every 30 min.

For the notification system using LINE Notify, user must register LINE Notify system to apply for the token id. By generating your own "personal access token" through LINE Notify, you can send messages by sending an HTTP POST request to the API endpoint. LINE Notify is a notification service that allows users to link to a web service and receive notifications from the official account "LINE Notify" that is provided by LINE. The function of the system is that the system will notify via LINE Access Token from Node-RED in case the temperature or humidity is abnormal. Users can customize the notification variables via Node-RED without having to edit the code in the WeMos D1 board. Figure 9 showing the example of the using LINE Notify in Node-RED. The msg.payload data will go through function and in this function we have set the parameter if course. User can change the condition for the notification anytime using Node-RED.

In the controlling system, it will wait for a publish topic and message from Node-RED through the UI. The operation of this system is the opposite of monitoring system. In the controlling system, WeMos D1 will subscribe

phpPgAdmin: PostgreSQL?: bananas drying plant

Query Results

temperature1	temperature2	temperature3	humidity1	humidity2	humidity3	sensor_date	sensor_time
31.3	31.31	31.3	46	45.9	45.99	2022-08-06	09:02:00
31.4	31.41	31.4	45.7	45.6	45.69	2022-08-06	09:32:03
33.3	33.31	33.3	36.6	36.5	36.59	2022-08-06	10:02:06
35.9	35.91	35.9	27.5	27.4	27.49	2022-08-06	10:32:09
34.1	34.11	34.1	32.3	32.2	32.29	2022-08-06	11:02:11
33.5	33.51	33.5	33.2	33.1	33.19	2022-08-06	11:32:13
32.4	32.41	32.4	35.9	35.8	35.89	2022-08-06	12:02:16
33.7	33.71	33.7	33.3	33.2	33.29	2022-08-06	12:32:18
33.8	33.81	33.8	31.6	31.5	31.59	2022-08-06	13:02:20
34.8	34.81	34.8	27.6	27.5	27.59	2022-08-06	13:32:23

Fig. 8 Shown the data has inserted into PostgreSQL database

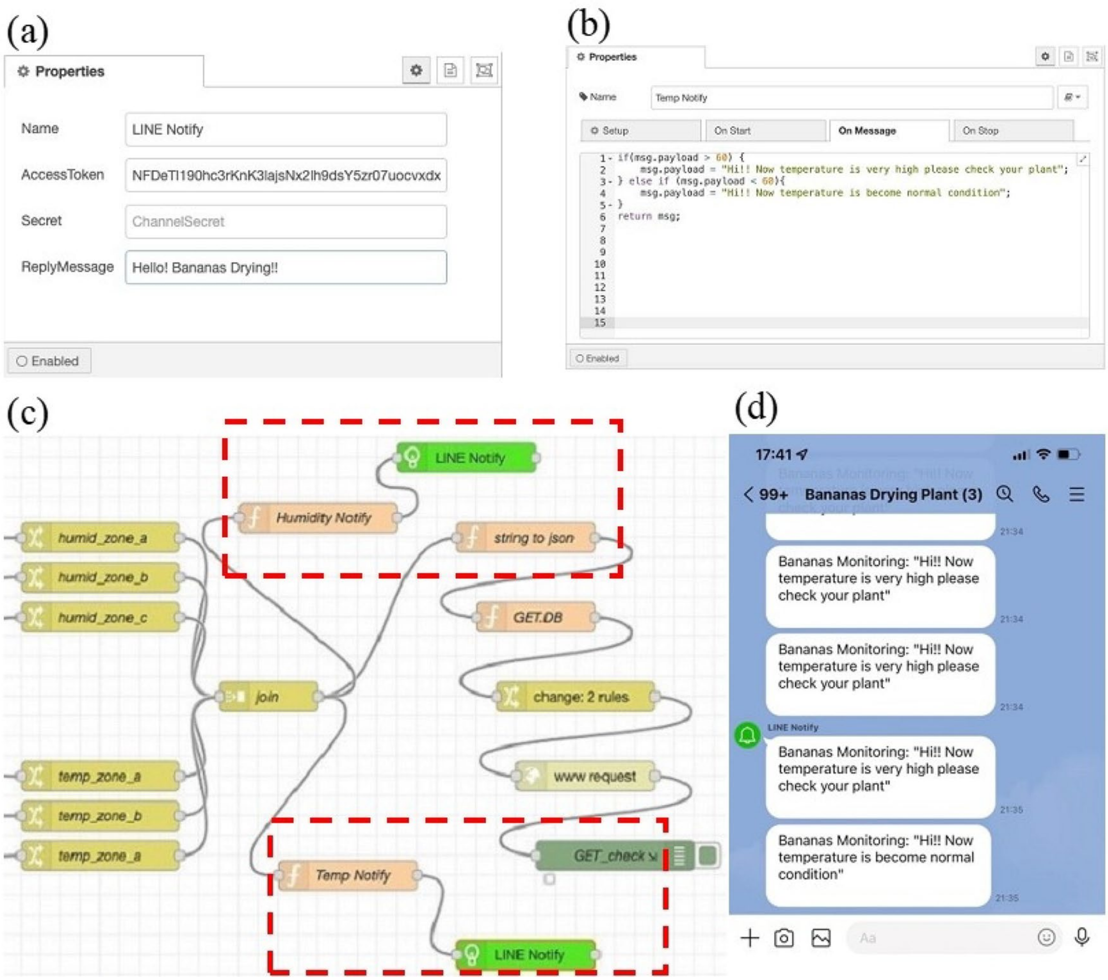

Fig. 9 LINE notify trigger flow. **a** Adding the access Token id, **b** Node-RED flow, **c** the notification variables, **d** LINE notify interface

to wait for publish topic/message from Node-Red, while monitoring system, Node-RED will subscribe to receive values from publish of WeMos D1. When WeMos D1 receives Topic/message: On/OFF from Node-Red (Fig. 10), system will execute Control the power system as the device is connected.

The generated web-based UI from node-red-dashboard module use to show the real-time data as a MQTT subscriber and pushing the message to control the power system as a MQTT publisher without typing the message as shows in Fig. 11. The UI button contained message payload like press active for sending "1_on" to topic "relay", then, relay 1 is on. In contrast, if UI button is inactive, the MQTT message is sending "1_Off" to topic "relay", then, relay 1 is off. The number of topic relay is dependent on hardware design, but in this work, we use 7 topics for 7 channels relay which present in the controlling section. Figure 12 shown all the Node-Red trigger in this works.

4 Conclusion and future work

This project was successfully built using low-cost IoT, MQTT, Node-RED and LINE Notify. The monitoring and controlling system have been exclusively designed for the PGSD. FOSS and OSH can be developed and applied for various purposed of users and it's very helpful of this works. This project can be implemented for other smart farming such as poultry farm, herb plant and for large scale outdoor farming by making a few changes. This project can be further improved by adding more sensor, camera. LINE Notify

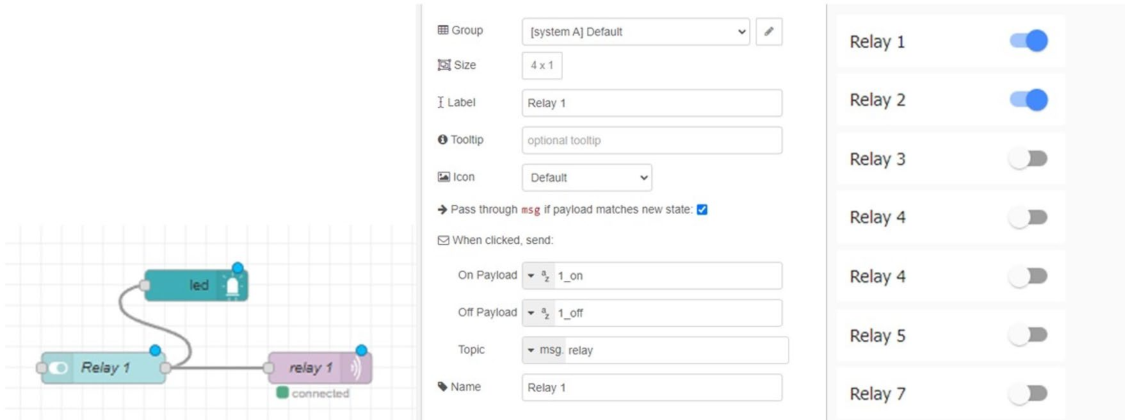

Fig. 10 UI button for publishing the MQTT message to WeMos D1

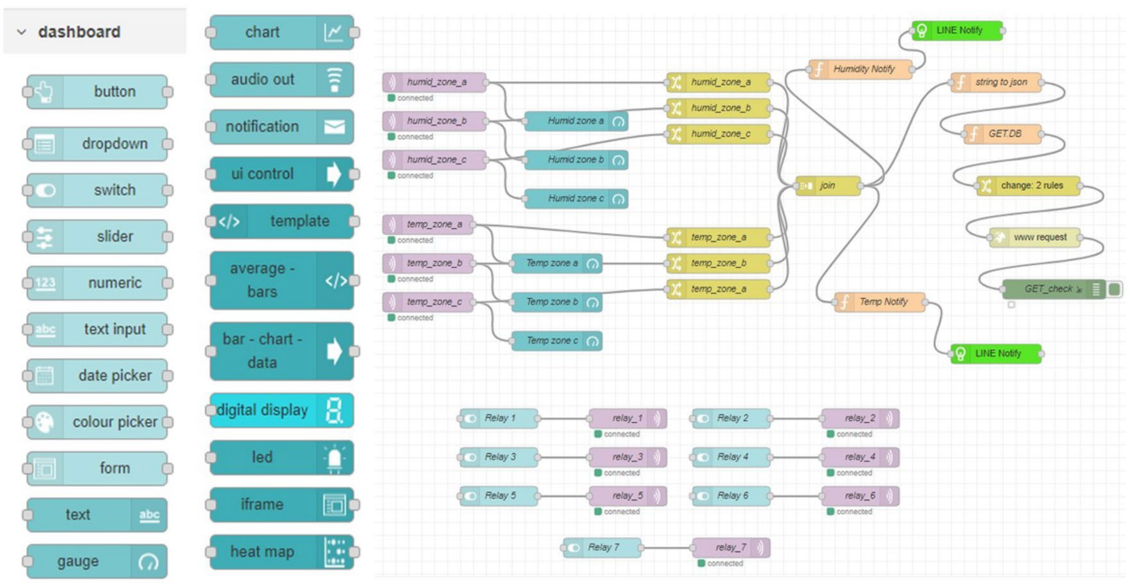

Fig. 11 UI flow wiring using node-red-dashboard

is easy to use for notification. In the future work, the system can be sending all the information and image capture from camera not only to LINE notify but email also can be sent. GIS spatial analysis can improved the accuracy for all values as raster map inside the PGSD. The real-time spatial data analysis can be developed to display the raster data instead of only shown the data as points of each node.

In the future, low-cost IoT technologies will be able to provide better smart farming, smart city according to the policy of BCG model Thailand 4.0.

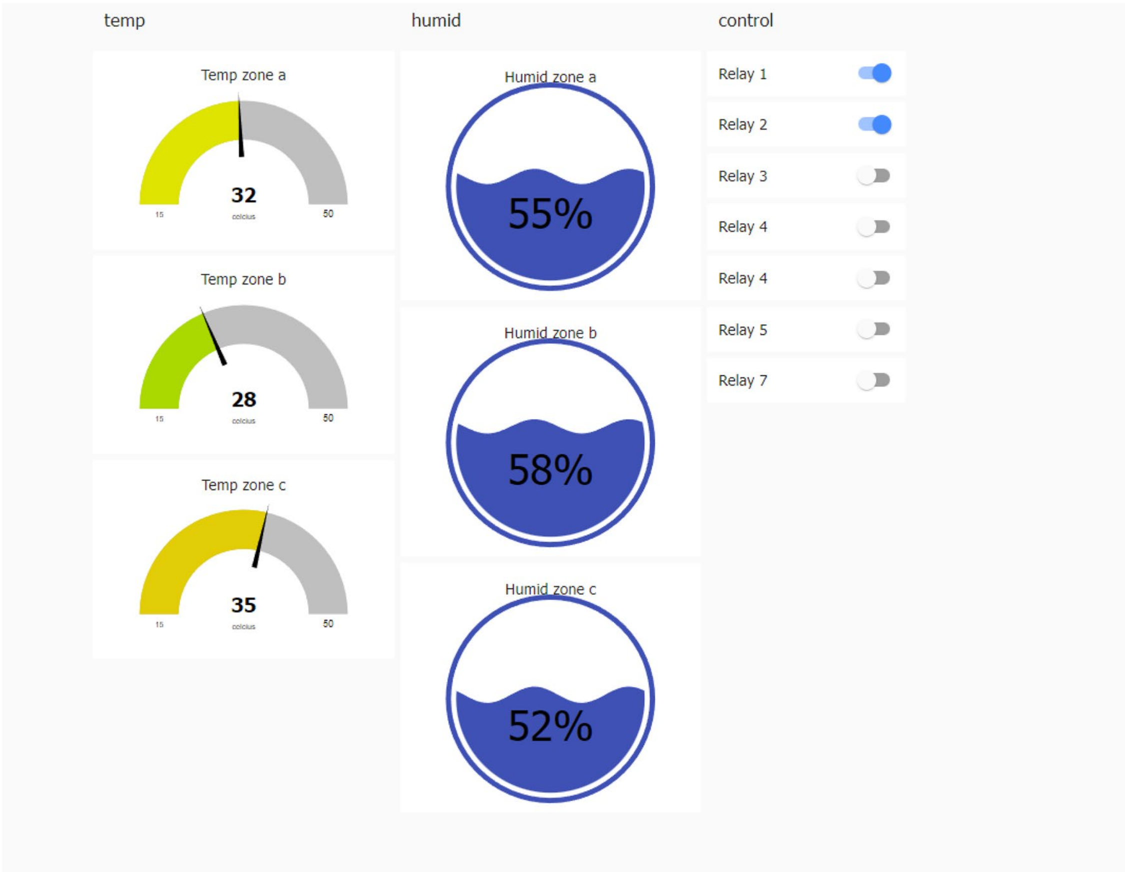

Fig. 12 The web-based UI for monitoring and controlling the system

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